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Technical Note N-1107

CHEMICAL OVERLAYS FOR SEAFLOOR SEDIMENTS

By

T. Roe, Jr., J. S. Williams, and H. J. Migliore

June 1970

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NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California 93041

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CHEMICAL OVERLAYS FOR SEAFLOOR SEDIMENTS

Technical Note N-1107

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by

T. Roe, Jr., J. S. Williams, and H. J. Migliore

ABSTRACT

Various materials and methods have been investigated to control the turbidity caused by the disturbance of seafloor sediments. The method selected as the most promising consists of the formation of a plastic film by extruding over the sediment a solution of a water-insoluble resin and plasticizers in a water-soluble solvent.

A formulation has been developed, and pilot model equipment to dispense it has been designed, fabricated, and is being evaluated.

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INTRODUCTION

Poor visibility is one of the many problems which man encounters when he carries out undersea operations. It has been reported that under ideal conditions, and at shallow depths, divers have been able to see clearly for 200 feet in all directions,¹ but generally the limit of visibility off the southern California coast is 50 feet. This limit is drastically reduced if seafloor sediments are disturbed so that an undersea "dust cloud" is created. Material of this type can remain suspended for hours with the result that work must be greatly curtailed or suspended. In salvage operations, any prolonged delay could result in partial or complete failure of the mission. As man begins to place permanent structures on the seafloor, sediment stabilization is a problem which will have to be solved during construction and operation of these installations.

Under initial sponsorship of the Supervisor of Salvage, Naval Ship Systems Command and later sponsorship of the Naval Facilities Engineering Command, the Laboratory undertook an investigation of materials and methods to produce an overlay on seafloor sediments to prevent the disturbance of those sediments with subsequent loss of visibility.

The overlaying of seafloor sediments can be accomplished in several ways: (1) by the laying down and anchoring of a sheet; (2) by in-place pouring of hydraulic mortar; and (3) by formation of an in-place film. The laying down and anchoring of a mat has the advantage of providing a strong cover ready for use. It has the disadvantages of requiring that the edges of adjacent mats must be lapped because they cannot be bonded to one another and that equipment large enough to give a suitable coverage would be unwieldy. The in-place pouring of hydraulic mortar presents a considerable logistics problem and should be used only when a permanent foundation is required. The formation of an in-place film would require a material and equipment to produce an overlay, by chemical or physical means, to cover the sediment. This could be readily dispensed at site from rather simple equipment and would require relatively small quantities of materials. Therefore, the formation of an in-place film seemed to be the best approach, and three possible methods to accomplish it were considered: (1) by formation of a polymer sheet by chemical reaction at the site; (2) by formation of a gel by increasing the viscosity of a liquid because of a low ambient temperature at the site; and (3) by formation of a plastic film at the site by casting from a compatible solvent system.

INVESTIGATION AND DEVELOPMENT OF OVERLAY MATERIALS

Formulation of Overlays by Chemical Reaction

Polyacrylamide. Acrylamide can be polymerized in a soil formation, and a proprietary product is sold for this purpose. Oceanographers³ have used this chemical grout in high concentrations in taking ocean bottom core samples. A description of their technique was obtained and the two solutions required to produce the grout were made up as follows: The first solution is prepared by dissolving acrylamide (430 g.) in water and adding dimethylaminopropionitrile (100 ml.). This solution is diluted to 1000 ml. The second solution is prepared by dissolving ammonium persulfate (500 g.) in water and diluting to 1000 ml.

Mixing 3:1 proportions of the first and second solutions and dispensing the resulting solution above a submerged sediment sample produced a gel in 20 minutes at 35°F. This method was abandoned because the acrylamide, before polymerization, is slightly neurotoxic and thus would not be suitable for diver use.

Alginic acid. Under contract to the Supervisor of Salvage, U. S. Navy, Battelle Memorial Institute^{4,5,6} developed a two-component overlay method in which sodium alginate containing titanium dioxide as a weighing agent is insolubilized by treatment with dilute hydrochloric acid. This method was evaluated at the Naval Civil Engineering Laboratory (NCEL), and additional information on it is included in the EQUIPMENT DEVELOPMENT section of this report. The overlay formed instantly and had fair mechanical properties. Its surface was quite slippery, and when walked upon, it tended to extrude or creep out from under one's feet and break up. It had some resilience and very low tensile strength. If a large area is to be covered, adjacent layers of this material cannot be bonded to one another, but must be overlapped or cross-hatched. Because of its requirement for two components, its marginal mechanical properties and its inability to bond to itself, this method is not recommended for future development.

Formation of Overlays by Increasing the Viscosity of a Liquid

Gelatin. Edible gelatin will dissolve readily in the cold in 1 N sodium salicylate. When a 32 percent gelatin solution was poured into sea water at 40°F, a firm gel formed. At 48°F, a soft gel formed.

Tests were performed at SEALAB II with three different concentrations of gelatin in 1 N sodium salicylate: 12 percent, 22 percent, and 32 percent. Divers reported that in the 47°F water, the 12 percent solution dispersed, but the 22 and 32 percent solutions sank just below the mud surface and formed a sticky gel layer. Thus, even a concentration of 32 percent, temperatures near 40°F are required to yield a good overlay, and this temperature restriction limits the method to depths in excess of 2500 feet except in polar areas.

Formulation of Overlays by Casting a Film⁷

Synthetic resins. The initial work on this approach involved beaker experiments with solutions of polyvinyl chloride or saran resins in solvents such as dimethyl sulfoxide, dimethylformamide-carbon tetrachloride, and dimethylformamide-chloroethanol. The migration of the water-soluble solvent component into the water left a resin film covering the bottom of the beaker. Good overlays were produced with these materials, but the toxicity of the solvents made them unsuitable for use where they would come into contact with humans. Further investigations into possible materials led to the use of 2-(2-ethoxyethoxy)-ethanol as the solvent and polyvinyl butyral as the resin. To increase the specific gravity and to act as a plasticizer, a chlorinated biphenyl mixture was added. However, it was noted that this plasticizer tended to be dispersed in the water by the solvent, and a white suspension was formed. The addition of a second plasticizer, dibutyl phthalate, solved this problem. Rhodamine B dye was added as a colorant because it is quite visible under water.

A typical overlay solution has the following composition:

2-(2-ethoxyethoxy) ethanol	20 gallons
Polyvinyl Butyral	6 pounds
Chlorinated B'phenyls	80 pounds
Dibutyl Phthalate	44 pounds
Rhodamine B	Color to suit

The viscosity of this solution determined at 23°C on a Brookfield Viscometer was 242.5 centipoises. The specific gravity at 24°C was 1.1 grams per milliliter. Therefore, when extruded through a narrow slit dispensing head under water this solution settles gently to the bottom in form of a ribbon, and a thin film forms at the solution-water interface. As the solvent migrates into the water, this film becomes thicker and tougher.

Because it is temperature independent, requires one solution, will bond to itself, and yields good films, this method was selected as the most promising for the production of seafloor sediment overlays.

EQUIPMENT DEVELOPMENT

Much of the success of the chemical overlay technique is contingent upon an effective dispensing system. The design of such a dispensing system must account for the myriad complications that are generated by working with a high viscosity, "sticky" fluid. Any candidate dispensing system must satisfy the following design parameters: (1) simple to operate, (2) reliable, (3) chemically compatible with the overlay solution, (4) able to produce a uniform overlay (no holidays, no thick regions), (5) able to maintain an

adequate flow rate, and (6) non-clogging. During the initial work on the development of overlay materials, the dispensing of candidate solutions was accomplished by pouring them down a metal spatula blade into a beaker of sea water. Later small extrusion heads, approximately 2-1/4 inches wide, were designed and fabricated. These, in conjunction with a glass tube reservoir and a rubber bulb, were used to dispense overlay materials in a tray of sea water (Figure 1). The effect of slit widths from 1/32-to 1/8-inch was noted. The first field dispensers were an amplification of this laboratory design. The dispensing head was a brass tube 36 inches wide with a 1/16-inch wide axial slit (Figure 2). A steel tank was used for storage, and flow was achieved by pressurizing this tank with compressed air. Experiments on this first field dispensing system indicated that volumetric flow rates had to be increased and that sealing was necessary to prevent clogging when the flow was stopped and restarted in situ.

Concurrent with NCEL's work, Battelle Memorial Institute developed a two-component overlay system. The equipment for this system consisted of two 55-gallon reservoirs, two 3.5-horsepower motors, two pumps, two lengths of 3/4-inch "garden hose", and a two-component dispenser (Figure 3). The bottom foil of the dispenser divided the acid and polymer into three planes (Figure 4). As fluid flowed from the rear of the dispenser, the components contacted each other and reacted (Figure 5). Because the polymer did not set up unless it reacted with the acid, the Battelle dispenser did not encounter "sticking" or clogging problems.

The next phase of the NCEL work involved designing a pilot dispensing system. The pilot dispensing system consisted of a 55-gallon reservoir, a 3.5-horsepower gasoline engine, a rotary pump, a 50-foot length of air blower hose, a pressure gauge, and two 30-inch dispensers. One dispenser was made of Schedule 40 PVC pipe with an axial slit down the bottom of the tube (Figure 6). As pumping pressure was applied, the slit opened and allowed chemical overlay solution to flow out. The other dispenser was a rigid-rolled copper tube with a 0.06-inch axial slit.

The pilot dispensers were tested in a 50- by 100-foot sand bottom, shallow-water pool. After initial testing, the most salient results were the following: (1) the rigid wall dispenser produced a uniform overlay, but the 0.06-inch opening was too great and produced an undesirably thick overlay; (2) the rigid wall dispenser was sensitive to clogging even with the incorporation of various types of external seals; (3) the flexible wall dispenser was intrinsically self-sealing; (4) the flexible wall dispenser produced an overlay with a variable cross section, i.e., undesirably thick and thin regions and holidays.

In light of these results, a hybrid dispenser was produced which would combine the advantages of the rigid and flexible wall design (Figure 7). Its basic configuration utilizes a flexible, PVC tube

with an axial slit. Adjustable stops were added to restrict the maximum slit opening (Figure 8). The stops permitted adjustments for hoop stress and pressure differences along the PVC tube and permitted adjustments for the flow thickness of the solution. In effect, the uniformity and the thickness of the overlay could be controlled.

Initial tests of this hybrid design were very promising. By restricting the maximum slit opening to 0.05-inch, a tough, uniform overlay was achieved (Figure 9). The thickness of the cast overlay was approximately 0.05 inch, with 0.1 inch in overlapped regions. The coverage was 2.5 square feet per gallon; at a material cost of \$2.50 per gallon, the chemical overlay method achieved bottom stabilization at a material cost of \$1.00 per square foot. It must be emphasized that this coverage and cost are the result of initial, pilot tests. Any future operational system would reflect a more judicious material selection and a more efficient dispenser where the cost could be significantly lowered. The mechanical strength of cast-overlay was good. A 10-foot long by 2.5-foot wide film could be raised off the bottom (Figure 10) and support itself without tearing; a man could walk on the overlay without destroying the film integrity.

The intent of the pilot model investigation was to gain experience and expertise to be used in designing a full-scale dispensing system for actual seafloor operation. Once this expertise was achieved, plans were formulated to build a 0- to 120-foot-depth dispensing system which is intended to be followed by a deeper-depth dispensing system.

OCEAN EXPERIMENTS

Experimental runs of fixed-slit dispensers with candidate overlay solutions were conducted in 25 feet of water off Santa Cruz Island and in 50 feet of water off Anacapa Island. These tests indicated that a chemical overlay dispensing system could not be entirely diver operated. Any system which requires divers to swim above the sediment with a dispenser and attached hose was found to be impractical because the dispenser and hose are too cumbersome to be handled in this manner. For this reason, two dispensing system prototypes were proposed: one to be used on the Laboratory's Construction Assistance Vehicle (CAV) (Figure 11), and a subsequent model to be used on a deep water submersible.

The CAV provides a load bed that can support a dispensing-system prototype. As the CAV cruises over an intended work site, the dispenser, suspended from the stern, can apply chemical overlay solution on the seafloor. Several parallel runs, overlapped at the edges, would completely cover the site. With the CAV in mind, the main features of the chemical overlay dispensing system include: (1) 600-gallon capacity, (2) at least 100 square feet per minute and 2000 square feet per hour coverage, (3) storage container to be pressure-compensated, and (4) stipulations to ensure convenience and efficiency in operator control.

The contract for the detailed design and fabrication of this dispenser prototype is to be completed by October 1970. This prototype will serve as a learning tool for the design of the deep water submersible system and, at the same time, be available for chemical overlay of any work sites at water depths to 120 feet.

CONCLUSIONS

1. Of several methods investigated for producing overlays on seafloor sediments, the most promising is the formation of a plastic film by extruding over the sediment a solution of water-insoluble resin and plasticizers in a water-soluble solvent.
2. The dispensing of overlay solutions must be conducted from a submersible vehicle rather than by swimming divers.
3. The dispensing head should be an adjustable-stop, flexible-wall type with a maximum opening of 0.05 inch.



Figure 1. Laboratory dispenser for single-component overlay system.

Figure 2. Thirty-six inch wide brass tube dispenser for single-component overlay system.

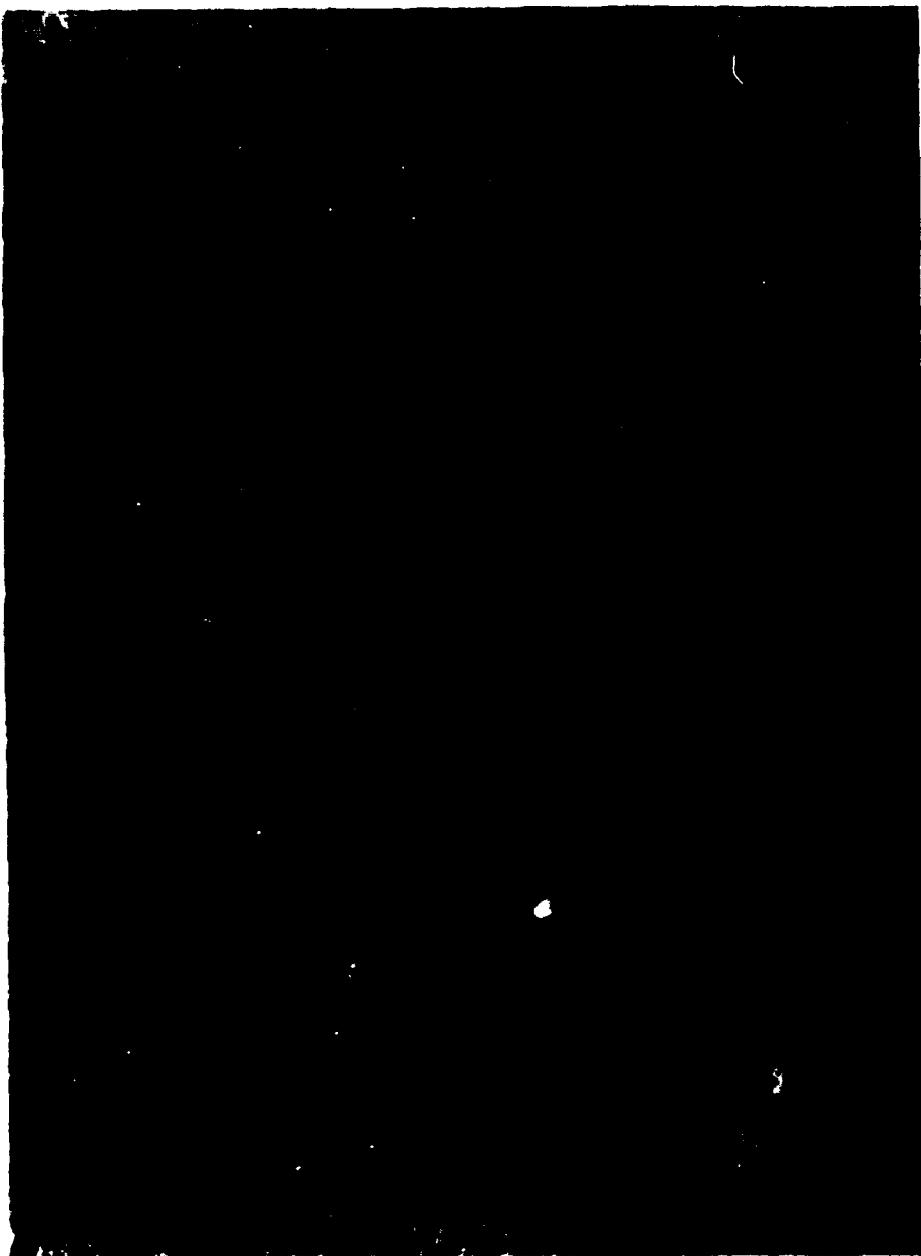




Figure 3. Battelle dispenser for two-component overlay system.

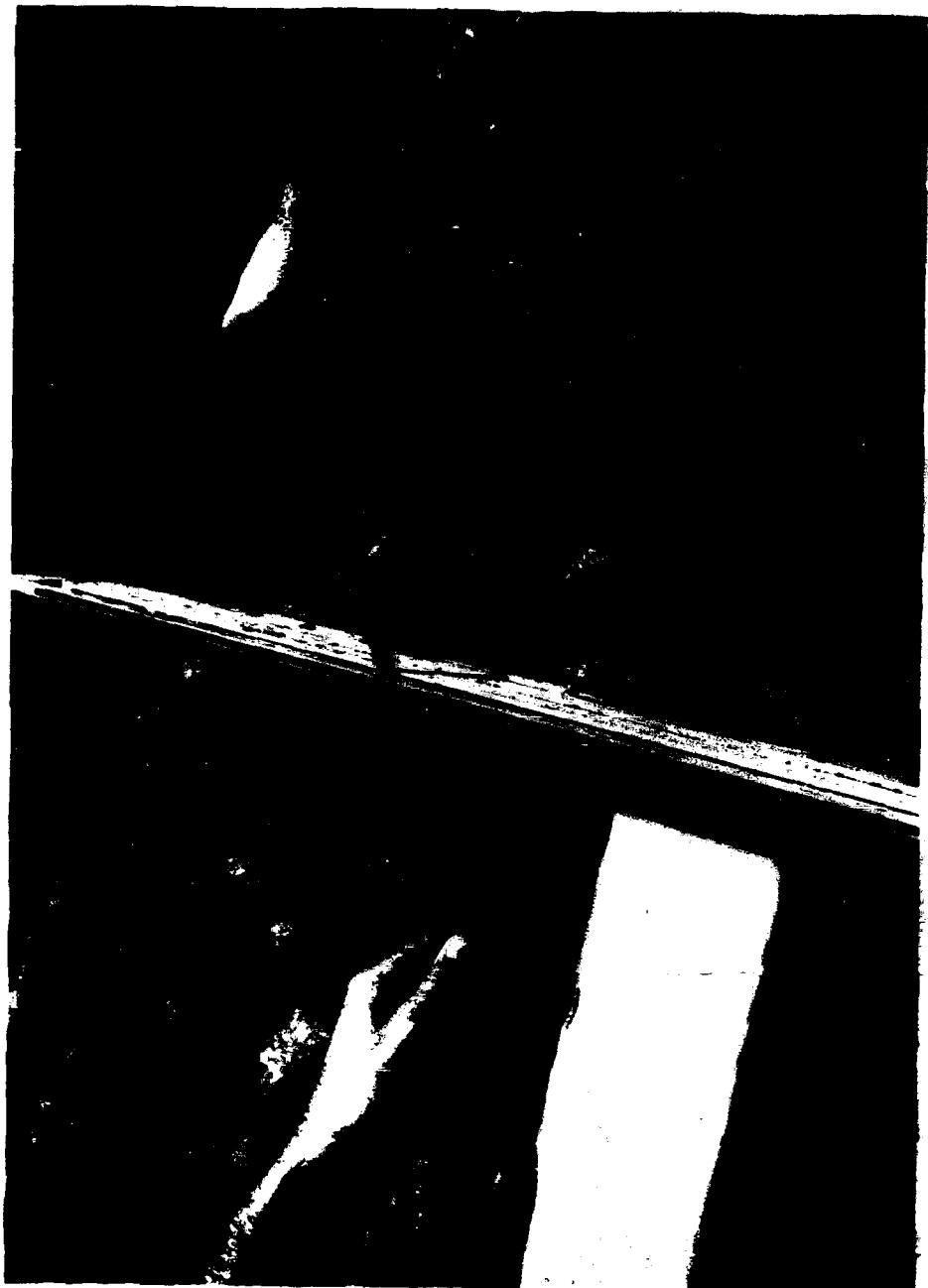


Figure 4. Dispensing plane-Battelle dispenser. Outer two are for acid solution and center one is for polymer solution.



Figure 5. Dispensing Battelle two-component overlay.

Figure 6. Single-component overlay dispenser.





Figure 7. Adjustable-stop dispenser for single-component overlay.



Figure 8. Adjusting stops while pumping of single-component overlay solution.

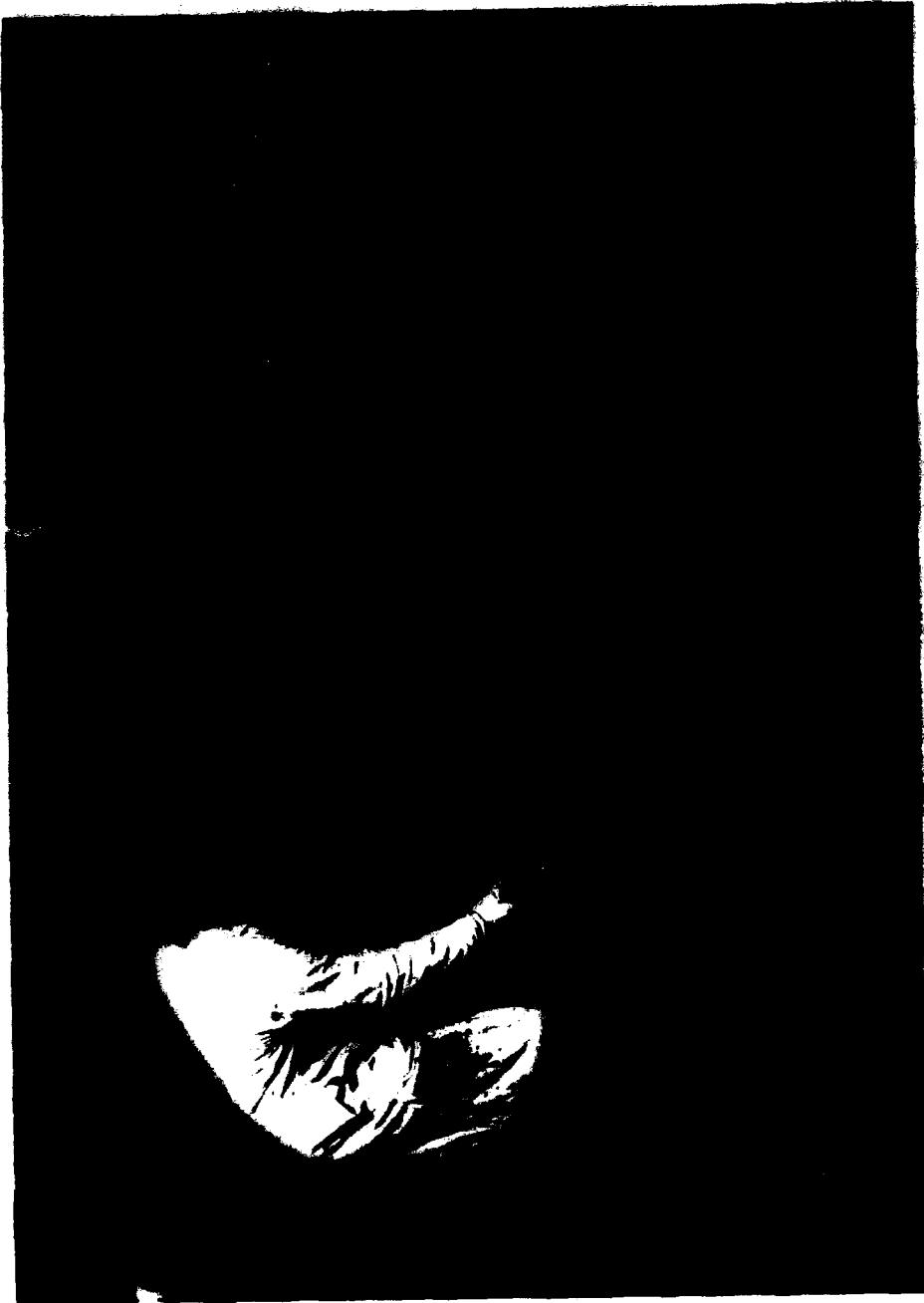


Figure 9. Dispensing single-component overlay.

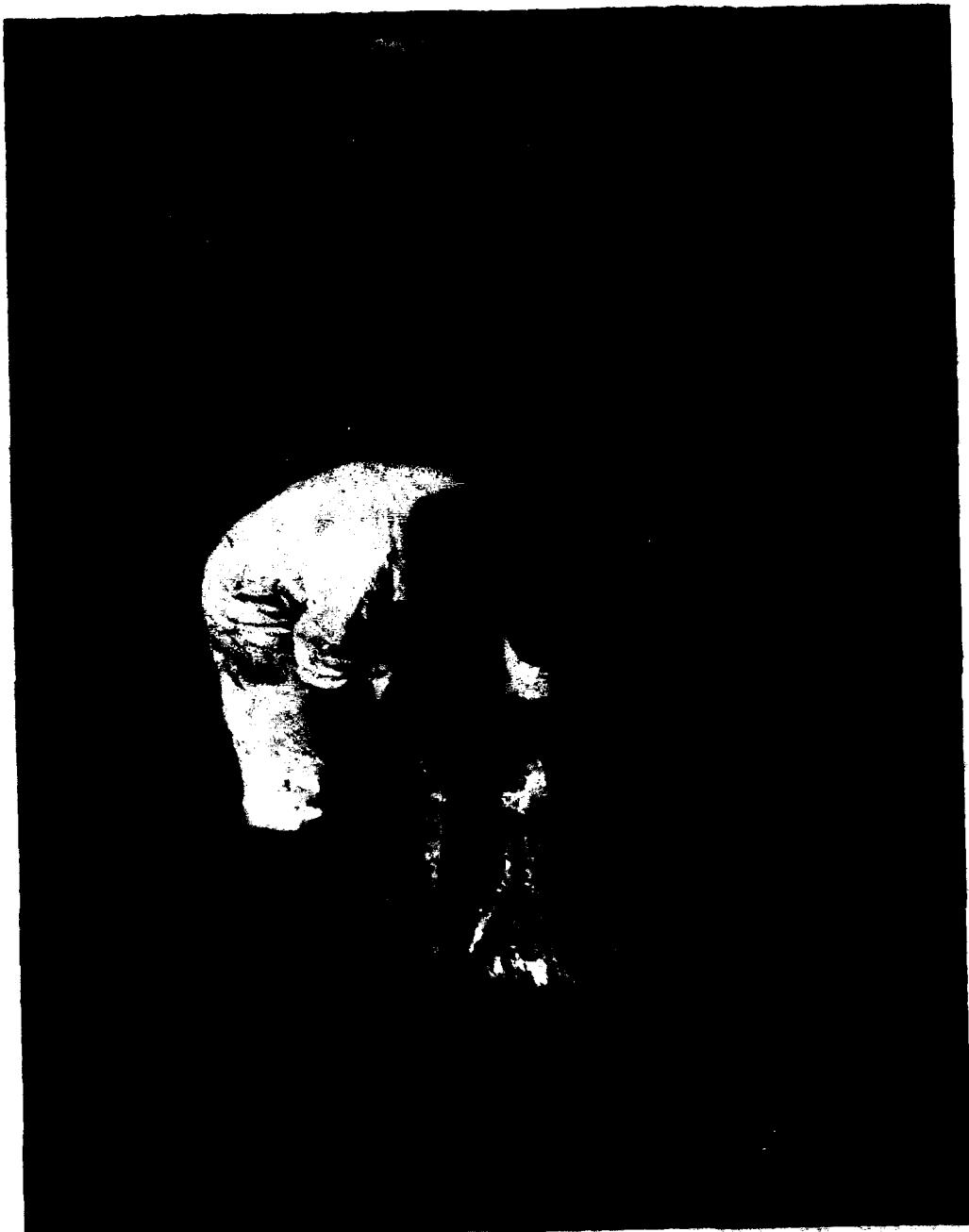


Figure 10. Lifting of single-component overlay film.



Figure 11. Construction Assistance Vehicle (CAV).

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